

**THE PETROLOGY AND GEOCHEMISTRY
OF THE WILIS AND LAWU VOLCANOES,
EAST JAVA, INDONESIA**

by

Ir. Udi Hartono

(Gadjah Mada University, Indonesia)

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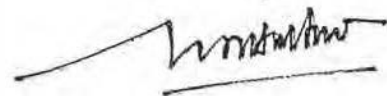
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To my wife, Sri, for her understanding and sacrifice, and
my children, Anton, Esti, Danang and Eliza
for their patience.

STATEMENT

This thesis contains the result of research done in the Geology Department, University of Tasmania, between 1989 and 1994. This thesis contains no material which has been accepted or submitted for the award of any other higher degree or graduate diploma in any tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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A handwritten signature in black ink, appearing to read 'Udi Hartono', written over a horizontal line.

Udi Hartono

University of Tasmania
August, 1994

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Abstract

The Wilis Volcanic Complex (WVC) and Lawu Volcanic Complex (LVC) are two volcanoes situated in the eastern part of the island of Java, Indonesia. The volcanoes are separated by an east-west distance of about 70 km, and are part of the chain of volcanoes which forms the eastern Sunda volcanic arc, a subduction-related feature that developed along the convergent boundary between the Indian-Australian oceanic plate to the south and Eurasian continental plate to the north.

The eruptive products of the WVC are classified into five groups based on morphostratigraphy and lithology, these are, from oldest to youngest, the pre-caldera Klotok basalt and basaltic andesite, the pre-caldera Pawonsewu andesite, the caldera Ngebel high-Si andesite and dacite, the post-caldera Jeding basalt-andesite, and the post-caldera Argokalangan andesite. Estimated temperatures of crystallisation of WVC magmas are about 1150°C for the basalts, about 1060°C for one olivine-bearing andesite, and range from 1035°C to 950°C for the andesites. Water contents of the magmas seem to have increased from basaltic through andesitic to dacitic. The bulk compositions of the WVC andesites suggest that the magmas may have formed in a relatively deep magma chamber, at depths of 7 - 18 km (equivalent to pressures of 2 - 5 kb), with small amounts of water. The WVC basalts may have begun to crystallise at even greater depths, presumably around 30 km (equivalent to pressures \approx 8 kb), and the dacites may have formed at about 18 km depth, possibly at slightly greater depths than the most andesites.

The geochemical and isotopic characteristics of both the pre-caldera Pawonsewu and post-caldera Argokalangan andesites are consistent with an origin largely by crystal-liquid fractionation from the pre-caldera Klotok basalt parental magma. Early fractionation of Ol+Cpx+Pl+Mg assemblages followed by Opx+Cpx+Pl+Mg \pm Apt assemblages could have produced the pre-caldera Pawonsewu and post-caldera Argokalangan andesites from Klotok-type basaltic

parental magma. However, whereas both the pre-caldera Pawonsewu and post-caldera Argokalangan andesites seem to have formed under open-system conditions, with the magma chamber being replenished by new magmas, assimilation of some crustal material may have been involved during the generation of the pre-caldera Pawonsewu andesite.

The origin of the caldera Ngebel high-Si andesite and dacite is more difficult to interpret. Major, trace and REE characteristics of the dacite (including High-Si andesite) are not consistent with an origin by simple fractionation from andesite. They may be related petrogenetically to the pre-caldera Klotok basalt/basaltic andesite, despite a silica-gap of about 7 wt % SiO₂. Crystal fractionation involving the separation from Klotok-type basaltic parental magma of assemblages of Ol+Cpx+Pl+Mg followed by either Opx+Cpx+Pl+Mg, Pl+Amp+Mg or Opx+Pl+Amp+Mg, could explain the major element variation from the basalt to dacite. However, ⁸⁷Sr/⁸⁶Sr and $\delta^{18}\text{O}$ values increase with increasing SiO₂, Rb and Rb/Sr, and decrease with increasing MgO and Sr contents, suggestive of some crustal contamination during differentiation, and trace element modelling and the extremely high $\delta^{18}\text{O}$ (12.1‰ - 13.5‰) values of the amphibole phenocrysts from the dacite suggest that even more complex differentiation processes may have taken place.

The LVC is divided into two groups, i.e. Old Lawu which is characterised by hornblende-bearing andesites and Young Lawu which is composed of olivine-bearing andesites. Unlike Wilis, basalts are not found. The estimated temperatures of crystallisation of the LVC andesites range from 1250°C to 982°C for Old Lawu and from 1320°C to 986°C for Young Lawu. Amphibole-bearing andesite may have formed at depths of 6 - 7 km, whereas the more basic andesite could have formed at greater depths, perhaps up to 18 km. Old Lawu andesite seems to have developed by crystal fractionation in an open-system magma chamber with the magma chamber being replenished by new magmas. Crystal fractionation could also account for the geochemical variation within the Young Lawu andesites, although contamination may have also been partly responsible for the geochemical variations. It is not known whether both Lawu groups came from the same parental magma, or even if their parent was basaltic. A more speculative interpretation suggests that the Young Lawu andesite may have resulted from fractionation of a mantle-derived basaltic parental magma, whereas the Old Lawu andesite more probably derived from a basaltic andesite parental magma.

produced at the upper mantle - lower crust as a result of reaction between mantle-derived magma and anhydrous ferromagnesian phases.

Zr/Nb, $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{143}/^{144}\text{Nd}$ values of the WVC basalts and the $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{143}/^{144}\text{Nd}$ values of LVC andesites suggest that MORB mantle exists in the mantle wedge beneath these volcanoes. The REE patterns of the WVC basalts and Young Lawu andesites are inconsistent with models calling for residual amphibole in the source region, but may be adequately modelled by melting of spinel lherzolite.

Wheller et al (1987) identified four regional along-arc sectors in the magmatism of the Sunda-Banda arc. They placed the transition from their West Java to Bali sector between Lawu and Wilis and proposed that the geochemical and isotopic differences reflected a greater involvement of crustal material in the sources of the magmatism. It is here argued that these differences arose because the effects of crustal assimilation are more pronounced in the Lawu Volcanic Complex than in the Wilis Volcanic Complex, possibly because the arc crust is thinner under Wilis than beneath Lawu.

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C O N T E N T S

	Page
Statement i
Abstract ii
Acknowledgments v
Contents vii
List of Tables xii
List of Figures and Plates	..... xvi
 CHAPTER 1. INTRODUCTION	 1
1.1. Background of Research	..... 1
1.2. Research Scope	..... 3
1.3. Location and Access	..... 3
1.4. Fieldwork and sampling	..... 5
1.4. Analytical Techniques	..... 7
1.5.1. Whole rock geochemistry	..... 7
1.5.2. Mineral Chemistry	..... 8
1.5.3. Isotope geochemistry	..... 8
1.5.4. Potassium-Argon Analyses	..... 9
 CHAPTER 2. GEOLOGY AND TECTONIC SETTING	 10
2.1. Introduction	..... 10
2.2. Regional Tectonic Setting of the Sunda-Banda arc	..... 10
2.2.1. Crustal structure	..... 13
2.3. Regional Geology of Java and the Solo Zone	..... 15
2.4. Geology of the Wilis Volcanic Complex	..... 19
2.4.1. General Geology	..... 19
2.4.2. Morphostratigraphy of the WVC	..... 21
2.4.3. The geology around Lake Ngebel	..... 31
2.4.4. Potassium-Argon data	..... 35
2.4.5. Structural geology	..... 37
2.4.6. Eruptive history	..... 37
2.4.7. Summary	..... 38
2.5. Summary of Geology of the Lawu Volcanic Complex	..... 39

CHAPTER 3. PETROGRAPHY AND MINERAL CHEMISTRY	..... 41
3.1. Introduction	..... 41
PART I. THE WILIS VOLCANIC COMPLEX	..... 41
3.2. Petrography and Mineralogy	..... 43
3.2.1. Classification	..... 43
3.2.2. Petrographic characteristics	..... 45
3.3. Mineral Chemistry	..... 53
3.3.1. Plagioclase	..... 53
3.3.2. Pyroxenes	..... 65
3.3.3. Olivine	..... 74
3.3.4. Amphibole	..... 80
3.3.5. Iron-Titanium Oxides	..... 82
3.4. Disequilibrium between phenocrysts and groundmass	..... 85
PART II. THE LAWU VOLCANIC COMPLEX	..... 87
3.5. Petrography and Mineralogy	..... 87
3.5.1. Classification	..... 87
3.5.2. Petrographic Characteristics	..... 97
3.6. Mineral Chemistry	..... 93
3.6.1. Plagioclase	..... 93
3.6.2. Pyroxenes	..... 99
3.6.3. Olivine	..... 103
3.6.4. Amphibole	..... 106
3.6.5. Iron-Titanium Oxides	..... 109
 CHAPTER 4. WHOLE ROCK GEOCHEMISTRY	 111
4.1. Introduction	..... 111
PART I. THE WILIS VOLCANIC COMPLEX	..... 111
4.2. Major Elements	..... 112
4.2.1. Pre- and post-caldera basalts and basaltic andesites	..... 112
4.2.2. Pre- and post-caldera basaltic andesites and andesites	..... 116
4.2.3. Caldera high-silica andesites and dacites	..... 118
4.2.4. Major element relationship between stratigraphic groups	..... 128
4.2.5. Tholeiitic and Calc-alkaline trends	..... 120
4.2.6. CIPW Norm Compositions	..... 121

4.3. Trace Elements	..... 121
4.3.1. Pre- and post-caldera basalts and basaltic andesites	..... 121
4.3.2. Pre- and post-caldera basaltic andesites and andesites	..... 128
4.3.3. Caldera dacitic rocks	..... 130
4.3.4. Trace element relationships between stratigraphic groups	..... 132
4.4. Rare Earth Elements and Yttrium	..... 134
4.5. Summary of geochemical variation	..... 138
PART II. THE LAWU VOLCANIC COMPLEX	..... 142
4.6. Major Elements	..... 144
4.7. Trace Elements	..... 149
4.8. Rare Earth Elements and Yttrium	..... 156
4.9. Geochemical comparison between the LVC and the WVC	..... 160
4.10. Summary of geochemical characteristics	..... 163
 CHAPTER 5. ORIGIN OF GEOCHEMICAL VARIATION	 164
5.1. Primary versus secondary magmas	..... 164
5.2. Fractional crystallisation	..... 167
5.3. Pearce Element Ratios (PERs)	..... 169
PART I. THE WILIS VOLCANIC COMPLEX	..... 172
5.3.1. The Assemblage Test Diagrams	..... 172
5.3.2. Phase Discrimination Diagrams	..... 176
PART II. THE LAWU VOLCANIC COMPLEX	..... 181
5.3.3. Assemblage test diagrams	..... 181
5.3.4. Phase discrimination diagrams	..... 182
5.4. Major element " Least squares mixing " models	..... 182
PART I. THE WILIS VOLCANIC COMPLEX	..... 185
Basalts - Andesites	..... 187
Basalts - Dacites	..... 191
PART II. THE LAWU VOLCANIC COMPLEX	..... 196
Old Lawu	..... 198
Young Lawu	..... 202
5.4.1. Summary	..... 204

5.5. Trace Element Modelling	..... 204
PART I. THE WILIS VOLCANIC COMPLEX	..... 207
Basalts - Andesites	..... 207
Basalts - Dacites	..... 212
PART II. THE LAWU VOLCANIC COMPLEX	..... 216
Old Lawu	..... 216
Young Lawu	..... 220
5.5.1 Summary of the results of trace element modellings	..... 222
 CHAPTER 6. PHYSICAL CONDITIONS OF MAGMATIC CRYSTALLISATION	..... 226
6.1. Introduction	..... 226
6.2. Temperature Conditions	..... 226
6.3. Pressure conditions	..... 238
6.4. Comparison of the composition of WVC and LVC volcanics with experimental studies	..... 242
6.5. Summary	..... 249
 CHAPTER 7. ISOTOPIC STUDIES	..... 251
7.1. Introduction	..... 251
7.2. Sr and Nd Isotopes	..... 252
7.2.1 Analytical Procedures	..... 252
7.2.2. Sr and Nd isotopic characteristics of the WVC and LVC	..... 255
7.2.3. Comparison of Sr and Nd isotopic composition between the WVC, LVC, other Sunda arc volcanous and other island arc volcanics	..... 258
7.2.4. Correlation between $^{87}\text{Sr}/^{86}\text{Sr}$ and Major and Trace element Geochemistry	..... 263
7.3. Oxygen Isotopes	..... 265
7.3.1. $\delta^{18}\text{O}$ variations in the WVC	..... 267
7.3.2. Oxygen isotopes and crystal fractionation	..... 270
7.4. Combined radiogenic and stable isotopes	..... 276
7.5. Summary	..... 280

CHAPTER 8. PETROGENETIC DISCUSSION	..... 282
8.1. Introduction	..... 282
8.2. Stratigraphic geochemical trends of the WVC	..... 283
8.3. Magma genesis	..... 285
8.3.1. Magma sources	..... 285
8.3.2. Origin of the WVC and Young Lawu Andesite	..... 305
8.3.3. Origin of the WVC dacite and Old Lawu andesite	..... 308
8.3.4. Evidence of possible magma mixing	..... 311
CHAPTER 9. CONCLUSIONS	..... 314
REFERENCES	..... 318
APPENDIX	
1. Modal Analyses	..... 339
2 Plagioclase Analyses	..... 345
3. Pyroxene Analyses	..... 370
4. Olivine Analyses	..... 393
5. Amphibole Analyses	..... 397
6. Iron oxide Analyses	..... 406
7. Whole rock geochemical analyses	..... 409
8. Partition coefficient compilation	..... 423
9. Rock catalogues	..... 439
10A. Locality map of the WVC	Enclosed
10B. Locality map of the LVC	Enclosed